The NOCC Radio Science Subsystem – System Performance Validation for the DSN Radio Science and Very Long Baseline Interferometry (VLBI) Systems

A. L. Berman
TDA Engineering Office

The DSN Radio Science and Very Long Baseline Interferometry (VLBI) Systems are functionally similar in that both are concerned with the recording of the baseband output signals of open-loop receivers on either computer-driven magnetic tape units or high-rate digital magnetic tape recorders. In recognition of these similarities, a single Network Operations Control Center (NOCC) subsystem – the NOCC Radio Science Subsystem (NRS) – is being implemented to provide the system performance validation capabilities for both the Radio Science and VLBI Systems.

This article provides a functional description of the key characteristics, requirements, and operation of the NOCC Radio Science Subsystem.

I. Introduction

In 1977, the Deep Space Network (DSN) created the DSN Radio Science System, and in 1978, the DSN Very Long Baseline Interferometry (VLBI) System. These two DSN Data Systems are quite similar in that both are primarily concerned with the recording of the baseband output signals of open-loop receivers on either computer-driven magnetic tape units or high-rate digital magnetic tape recorders. In fact, much of the equipment at the Deep Space Stations (DSS) is shared between the two Systems (Ref. 1).

In general, all DSN Data Systems have a dedicated subsystem in the Network Operations Control Center (NOCC) which provides real-time system performance validation. Besides the already mentioned similarities between the Radio Science and VLBI Systems, both also operate at irregular and somewhat infrequent intervals, in contrast to the nearly continuous operation of other DSN Data Systems. Given the basic similarities between, and the irregular and relatively infrequent operation of, the Radio Science and VLBI Systems, it seemed both convenient and economical to implement a single NOCC subsystem which could provide system performance validation for both Systems. Such a subsystem is in the process of being implemented, and is referred to as the NOCC Radio Science Subsystem (NRS). Some capabilities now assigned to the NRS have been described in previous issues of *The DSN Progress Report*; these capabilities include radio metric graphics (Ref. 2), open-loop spectrum displays (Ref. 2), and planetary atmosphere-corrected predictions (Ref. 3).

This article provides a description of the key characteristics, functional requirements, and operation of the NOCC Radio Science Subsystem.

II. Functional Description of the NOCC Radio Science Subsystem

A. Definition

The NOCC Radio Science Subsystem, an integral element of both the DSN Radio Science and VLBI Systems, performs the following major functions:

(1) Radio Science Functions

(a) Generates graphical radio metric displays

(b) Generates open-loop spectrum displays from Spectral Signal Indicator (SSI) digital data

(c) Generates DSS Radio Science Subsystem (DRS) status, configuration, and control data displays.

(2) VLBI Functions

(a) Generates VLBI calibration and ancillary data displays

(b) Validates VLBI calibration and ancillary data via operator alarms

(c) Generates DRS status, configuration, and control data/displays.

NOCC Radio Science Subsystem functions and interfaces are illustrated in Fig. 1.

B. Key Characteristics

The key characteristics of the NOCC Radio Science Subsystem are listed below for Radio Science and VLBI applications:

(1) Radio Science Key Characteristics

(a) Generates graphical displays of radio metric data for use in validating and controlling the DSN Radio Science and Tracking Systems during critical phase operations.

(b) Generates open-loop spectrum displays for use in validating and controlling the DSN Radio Science System

(c) Provides displays in both NOCC and project Radio Science areas

(d) Provides up to 12 parameter radio metric (graphical) displays simultaneously

(e) Updates open-loop spectrum displays at five-second intervals

(f) Simultaneously processes both VLBI and Radio Science data.

(2) VLBI Key Characteristics

(a) Provides DRS status, configuration, and control data displays

(b) Provides displays of VLBI calibration and ancillary data in two-station comparative format

(c) Validates VLBI operations by comparing status, configuration, control data, and VLBI calibration and ancillary data to standards and limits

(d) Provides operator alarms for configuration errors, out-of-tolerance data, and NRS malfunctions.

C. Functional Operation

Functions and data flow of the NOCC Radio Science Subsystem are presented in Fig. 2. This figure can be referred to in conjunction with the following descriptions of functional operation.

1. Graphical Display of Radio Metric Data. Various radio metric data are accumulated, processed, and formatted in the Metric Data Assembly (MDA) of the DSS Tracking Subsystem (DTK). These data are then provided to the Communications Monitor and Formatter (CMF) for subsequent high-speed data line (HSDL) transmission to the NOCC Tracking Subsystem (NTK). After additional processing by the NTK, the radio metric data are provided to the NRS. The data are processed into graphical displays and are provided to the NOCC Display Subsystem (NDS) for display in the Network Operations Control Area (NOCA) and project Radio Science area. NOCA operators construct and control the graphical display through operator control instruction (OCI) inputs to the NDS.

2. Graphical Display of Open-Loop Spectral Data. Digital spectral data from the SSI of the DSS Receiver-Exciter Subsystem are transferred to the Occultation Data Assembly (ODA) of the DRS. The ODA formats and transmits the data to the NRS via wideband data line (WBDL). The NRS reconstructs the open-loop spectra and provides such replicated spectra to the NDS for display in the NOCA and project Radio Science areas. NOCA operators control the open-loop spectra displays through OCI inputs to the NDS.

3. Display of DRS Status, Configuration, and Control Data. DSS Radio Science Subsystem status, configuration, and control data during both Radio Science and VLBI operations are formatted by the ODA and passed to the CMF for subsequent HSDL transmission to the NRS. The NRS formats this data into displays and provides the data to NDS for display in the NOCA. NOCA operators control the DRS status, configuration, and control data displays through OCI inputs to the NDS.

4. **Display of VLBI Calibration and Ancillary Data.** VLBI calibration and ancillary data are accumulated in the MDA. The MDA transfers these data to the ODA for formatting. The ODA provides the formatted data to the CMF for HSDL transmission to the NRS. Within the NRS, VLBI calibration and ancillary data from two DSS are formatted into two-station comparative formats, and provided to the NDS for display in the NOCA. NOCA operators control the VLBI calibration and ancillary data displays through OCI inputs to the NDS.

5. **Validation of VLBI Calibration and Ancillary Data.** DRS status and configuration data and VLBI calibration and ancillary data are compared in the NRS to standards and limits received from the NDS. Configuration errors and out-of-tolerance data generate alarms, which are passed to the NDS for display in the NOCA. Additionally, the NRS generates alarms for some NRS malfunctions.

6. **Display of VLBI Data Accountability.** VLBI data accountability and VLBI fringe information are passed to the NRS from the VLBI Processor Subsystem. The NRS formats this data into displays and provides the data to the NDS for display in NOCA. In NOCA, operators control these displays through OCI inputs to the NDS.

7. **Provision of Status Data.** The NRS collects all alarm messages and passes these to the NOCC Monitor and Control Subsystem (NMC), for inclusion on the Network Performance Record.

III. Functional Requirements of the NOCC Radio Science Subsystem

This section describes the specific functional requirements of the NRS for the time period 1979 to 1983. The fundamental Network Operations requirement levied on the NRS is stated as follows:

The NRS shall provide the following DSN Radio Science and VLBI System data to the Network Operations Control Center in real-time:

(1) Status

(2) Configuration

(3) Performance

These data shall allow the Network Operations Control Team to:

(1) Evaluate system performance

(2) Effect reasoned real-time control decisions as required.

In addition, the NRS shall possess the general capability to simultaneously process data from either two or three DSS for the following configurations:

(1) Three DSS performing VLBI

(2) Two DSS performing VLBI and one DSS performing Radio Science

(3) Two DSS performing Radio Science

The following subsections A. through H. describe the functional requirements for each of the major functional capabilities provided by the NRS.

A. Functional Requirements for Graphical Display of Radio Metric Data

1. **Radio Metric Parameters to be Displayed.** The capability shall be provided to display radio metric data parameters at both S- and X-band (where applicable) versus the corresponding data time. The specific radio metric parameters to be displayed are listed in Table 1. The capability shall be provided to display these radio metric parameters with time modulo the full-scale time.

2. **Screen Display Capability.** Display capability shall be provided as follows:

(1) Full screen

(2) Half-screen vertical (two displays/screen)

(3) Half-screen horizontal (two displays/screen)

(4) Quarter screen (four displays/screen)

The capability shall be provided to display up to 12 parameters simultaneously, consistent with 3-quad-channel capability.

3. **Hard-Copy Capability.** Hard-copy capability shall be provided in NOCA.

B. Functional Requirements for Graphical Display of Digital SSI Data

The capability shall be provided to replicate, display, update, and distribute the CRT spectrum displays of the SSI.

1. **Display Capability**

a. Output Points. The number of output points (spectral lines) displayed shall be 400.

b. Amplitude Selection. Full-scale (displayed) amplitude shall be selected from: 18.75 dB; 37.5 dB; 75 dB; 150 dB.

c. Spectral Noise Floor Placement. The spectral noise floor placement within the display shall be selectable.

d. Alphanumeric Notational Information. The following alphanumeric notational information shall be included within each SSI display:

(1) Full-scale amplitude in dB

(2) Full-scale frequency (bandwidth) in kHz

(3) Number of averaged spectra per display

(4) DSS identification (ID)

(5) SSI channel selected

(6) SSI transform size

(7) Maximum power point signal-to-noise ratio (SNR)

(8) Maximum power point frequency

2. Display Update Capability. The capability shall be provided to update the display:

Requirement:	once per 30 seconds
Design goal:	once per 5 seconds

3. Display Distribution and Hard Copy Capability

a. Display Channels. The following SSI display channels shall be provided in NOCC and project Radio Science areas.

(1) Two channels, simultaneous operation

(2) One channel per 64 meter DSS

(3) Project Radio Science area displays shall be slaved to NOCC displays

(4) Channel control capability shall reside with the DSN Operations Chief

b. Hard Copy Capability. SSI display hard-copy capability shall be provided in NOCC.

4. DSS-NOCC Interface. Transmission between the DSS and NOCC shall be via wideband data line. A sample display of SSI digital data to be provided in NOCC is illustrated in Fig. 3.

C. Functional Requirements for Display of DRS Status, Configuration, and Control Data During Radio Science Operations

The NRS shall format and provide to the NDS displays of DRS status, configuration, and control data. A minimum set of these data shall be as follows:

1. DRS Status Display

(1) Program mode (idle, run, playback, etc.)

(2) Hardware status, including:

(a) Frequency Monitor Subassembly (FMS)

(b) Modcomp Computer

(c) Magnetic tape units

(d) Programmed Oscillator Control Assembly (POCA)

(e) Occultation Converter Subassembly

2. DRS Configuration Display

(1) Receiver channel select

(2) A-D conversion mode

(3) Sampling rate (s)

(4) SSI channel select

(5) Receiver filter select

3. DRS Control Data Display

(1) Predicts set ID

(2) FMS frequency

(3) Frequency offsets

(4) Time offsets

(5) Time-tagged Programmed Oscillator (PO) frequency

(6) Time-tagged PO frequency rate

4. DSS-NOCC Interface. Transmission between the DSS and NOCC shall be via HSDL.

D. Functional Requirements for DRS Display During VLBI Operations

The NRS shall format and provide displays to the NDS of DRS status, configuration, and control data during VLBI operations.

1. DRS Status Display

(1) Program mode (idle, run, playback, etc.)

(2) Hardware status, including:

(a) Modcomp Computer

(b) Magnetic tape units

(c) VLBI Converter Subassembly

2. **DRS Configuration Display**

(1) Receiver channel select

(2) Sampling rate

(3) Receiver filter select

3. **DRS Control Data Display**

(1) Recorder on-off

(2) Predict set ID

4. **DSS-NOCC Interface.** Transmission between the DSS and NOCC shall be via HSDL.

E. Functional Requirements for Display of VLBI Calibration and Ancillary Data

1. **Display Data Requirements.** The NRS shall format and display VLBI calibration and ancillary data from two DSS simultaneously and in two-station comparative format. The displays shall contain the data types listed in Table 2.

2. **DSS-NRS Interface.** Transmission between the DSS and NRS shall be via HSDL.

F. Functional Requirements for Validation of VLBI Calibration and Ancillary Data

The NRS shall utilize standards and limits to validate VLBI calibration and ancillary data. The data to be validated are:

(1) Configuration

(2) Status

(3) Other calibration and ancillary data (within limits)

The same set of data limits shall be used for validating each parameter at both DSS.

1. **VLBI Data Alarms.** The NRS shall provide alarms that result from the validation process for the following data types and operating conditions:

(1) All VLBI data types listed in Table 2

(2) DSS not pointing to correct source

(3) DSS not pointing to same source

(4) VLBI predicts missing for DSS

(5) Recorders not running at DSS

G. Functional Requirements for Display of VLBI Data Accountability

The NRS shall format and display VLBI data accountability and VLBI fringe information as provided by the VLBI Processor Subsystem.

H. Functional Requirements for Provision of Status Data to the NOCC Monitor and Control Subsystem (NMC)

The NRS shall provide its operational status to the NMC. In addition, the NRS shall provide all NRS alarm messages to the NMC for inclusion on the Network Performance Record; the expected list of such alarm messages is provided in Table 3.

IV. NRS Planned Implementation Schedule

The implementation schedule for ongoing and future implementation within the NOCC Radio Science Subsystem is as follows:

(1) Open-loop spectra display ..... April 1, 1980

(2) DRS status and configuration displays (Radio Science and VLBI) ..... Nov. 15, 1979

(3) VLBI calibration and ancillary data display ..... Nov. 15, 1979

(4) VLBI calibration and ancillary data validation ..... Nov. 15, 1979

(5) VLBI data accountability display ..... Nov. 15, 1979

References

1. Berman, A. L., "The DSS Radio Science Subsystem – Data Handling of Very Long Baseline Interferometry (VLBI) Data," in *The Deep Space Network Progress Report 42-46*, pp. 115-122, Jet Propulsion Laboratory, Pasadena, California, August 15, 1978.

2. Berman, A. L., "DSN Radio Science System Mark III-78 Real-Time Display Capability," in *The Deep Space Network Progress Report 42-40,* pp. 141-145, Jet Propulsion Laboratory, Pasadena, California, August 15, 1977.

3. Berman, A. L., "Planetary Atmosphere Modeling and Predictions," in *The Deep Space Network Progress Report 42-42,* pp. 125-129, Jet Propulsion Laboratory, Pasadena, California, December 15, 1977.

Table 1. Radio metric parameters to be displayed

Doppler frequency
Doppler pseudo residual
Doppler noise, including:
High rate
Medium-high rate
Medium-low rate
Low rate
High rate (data type 38)
S-X Doppler, discrete
S-X Doppler, summed
Received signal level
Angle 1
Angle 2
DRVID
DRVID noise
Pseudo-DRVID
S-X range
P_r/N_o

Table 2. VLBI calibration and ancillary data types to be displayed

Station configuration data:
Polarization (right or left circularly polarized)
Receiver bandwidth
Station clock offset
Comb generator frequencies and powers
Frequency dwell (time per receiver channel)
Station frequency standard
Antenna Pointing Subsystem (APS) mode
Recorders on-off
Traveling Wave Maser (TWM) used
S- and X-band system noise temperature
Calibration tone data:
Power
Frequency
Phase Stability
Weather parameters:
Temperature
Pressure
Dew point
Water vapor partial pressure
VLBI angle and angle residual data:
Source right ascension, declination
Local hour angle/declination angle and angle rate
Event and alarm conditions
VLBI source identification (ID)
VLBI source strength:
Predicted
Measured
DSS (40-character) alphanumeric information

Table 3. VLBI System alarms to be recorded on the network performance record

Single Station Alarms:
VLBI data received
Unable to pair DSS
No source tracked
Recording not started
Recording started
Clock offset not entered
Clock offset entered
Comb generator frequency not entered
Comb generator frequency entered
System noise temperature (SNT) not entered
SNT entered
Frequency standard change: XXXX
VLBI status change: XXXX
VLBI mode change: XXXX
APS mode change
Conscan mode change: XXXX
Meteorological Monitor Assembly (MMA) data not received
MMA data received
Status data not received
Status data received
Angle data not received
Angle data received
Comb generator signal missing/
Wrong channel: X
Comb generator signal corrected
Bandwidth SNR not measured
Bandwidth SNR measured
Channel not in use: X
Source change/antenna not moved
Source change: XXXXXXXXX
Session terminated
VLBI Pair Alarms:
Sources do not match
Pointing does not match
Predicts do not match
VLBI pair
End session both DSS
Configuration not identical
Both DSS not recording
Source change one DSS: XX
Source change both DSS

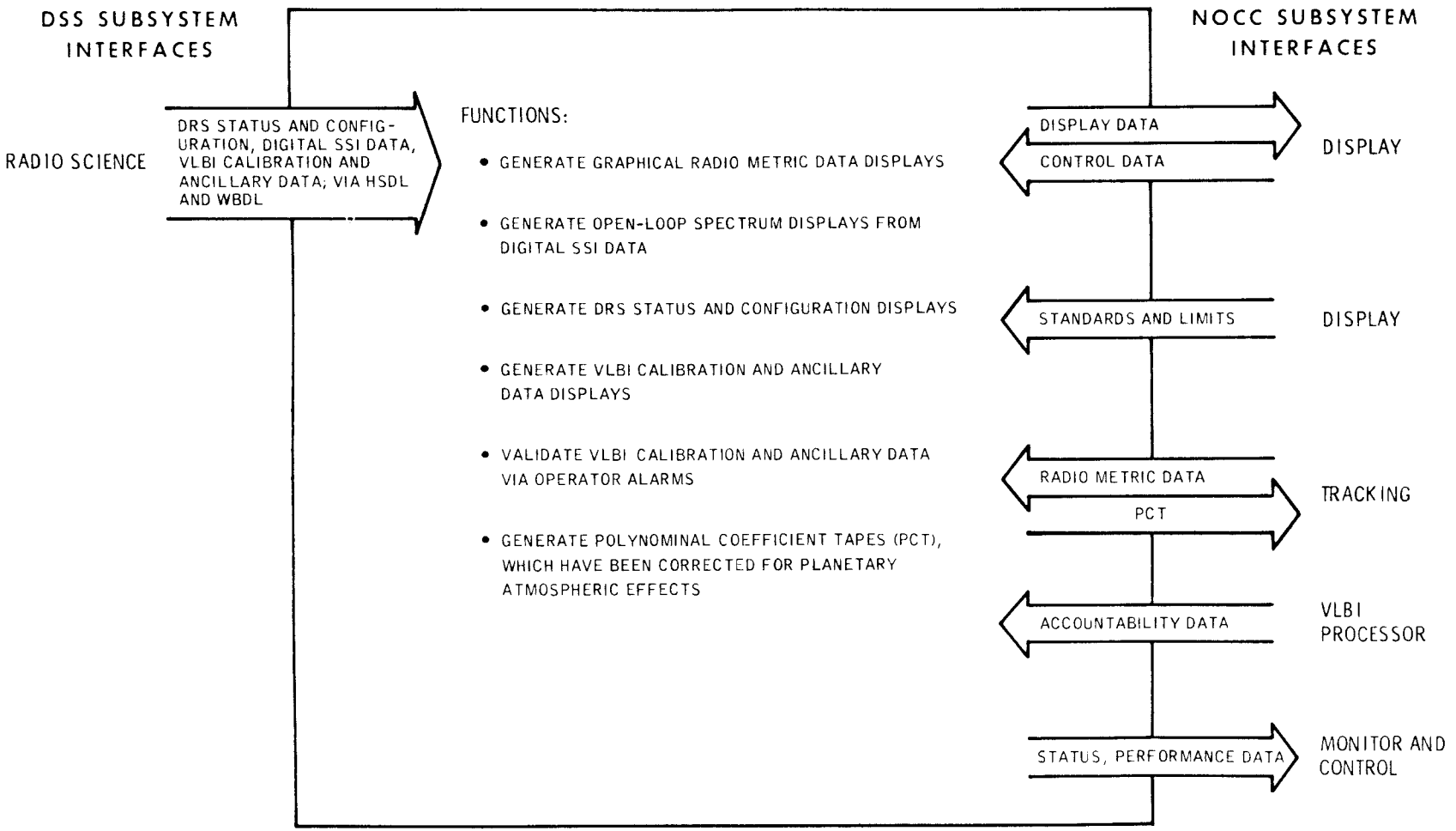


Fig. 1. NOCC Radio Science Subsystem functions and interfaces

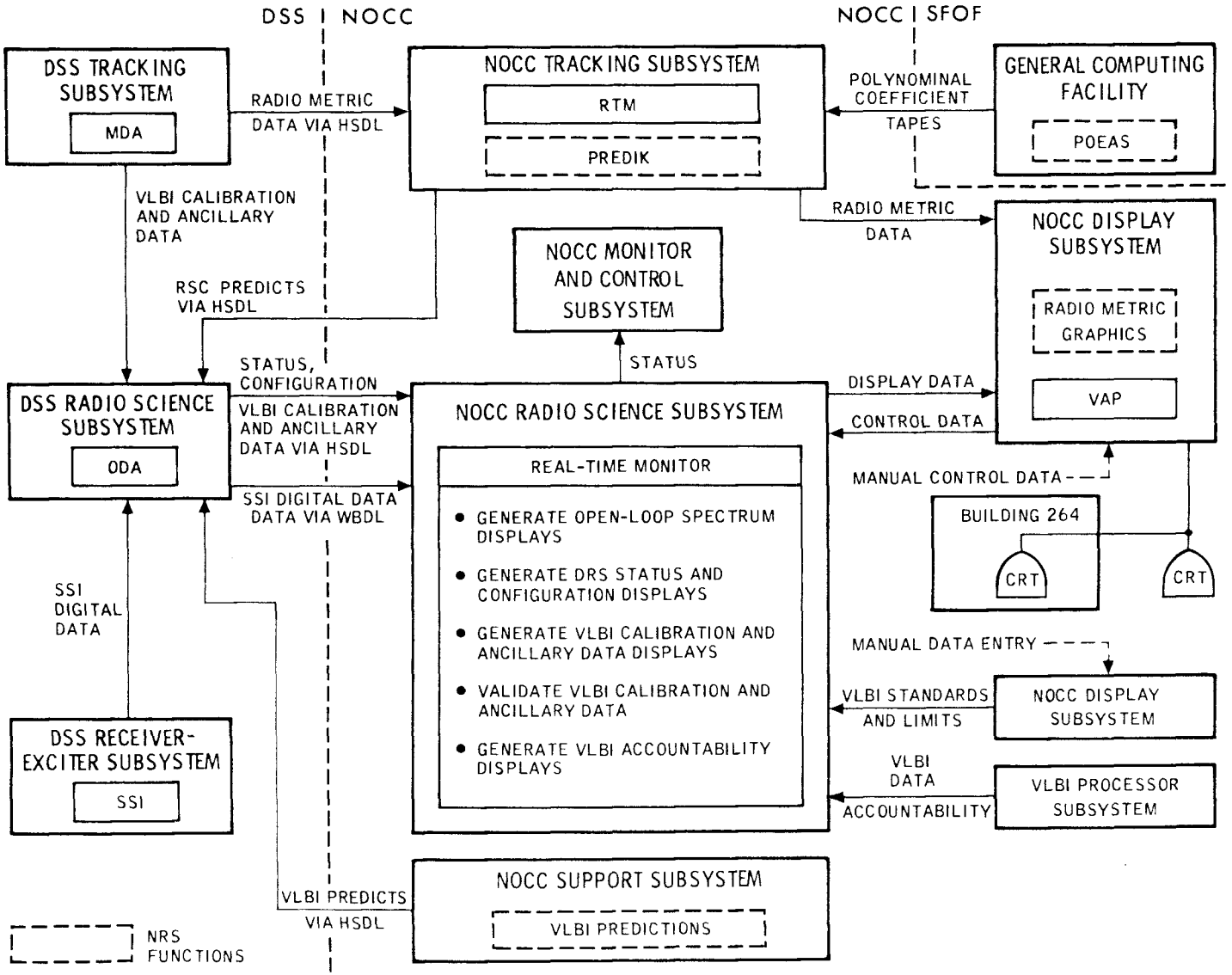
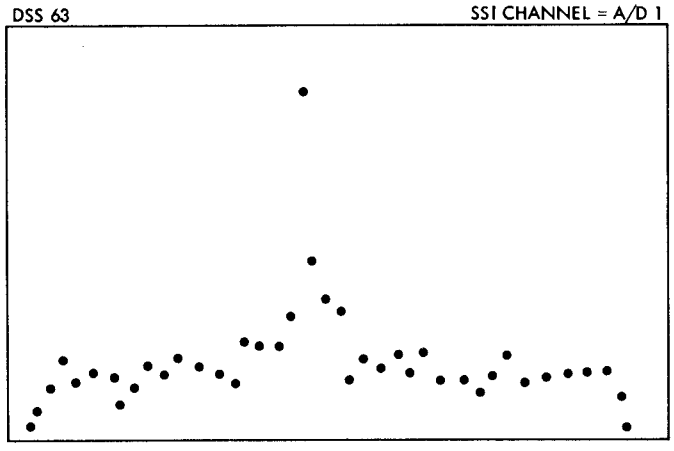


Fig. 2. NOCC Radio Science Subsystem functions and data flow



FULL SCALE AMPLITUDE = 52 dB

FULL SCALE FREQUENCY BANDWIDTH = 10.0 kHz

NUMBER OF AVERAGED SPECTRA = 32

MAXIMUM POWER POINT SNR = 30 dB

MAXIMUM POWER POINT FREQUENCY = 4.55 kHz

TRANSFORM SIZE 4096

Fig. 3. Sample display of SSI digital data